Safety Assessment

Two aspects of Yucca Mountain position it well as the site of a nuclear waste repository. The first is that no one lives within 14 miles of the sprawling mountain, although roughly 1,300 people have made the Amargosa Desert their home, preferring the desert's stillness to the kinetics of Las Vegas just 90 miles away.

The second is that the mountain sits in one of the driest locales in the United States. Water is the bane of the repository, because given near-eternity, the mighty water droplet can corrode and/or dissolve nearly anything.

The repository, a series of steel-lined tunnels dug within the middle of the ridge and roughly 1,000 feet beneath the surface, will have several barriers that prevent water from reaching the radioactive material. The waste will be sealed inside enormous stainless steel canisters, each of which will itself be sealed inside a canister of 2-inch-thick stainless steel, which will be sealed within a third canister made from a super-corrosion-resistant nickel alloy. The massive "waste packages" will be loaded end-to-end into the tunnels and covered with a titanium "drip" shield. When all tunnels are filled, the repository will be closed for all time.

Scientists assessed what was likely to happen to the waste during the millennia by using what's called a total system performance assessment (TSPA). They first attempted to identify all events that might befall the repository. Then they estimated the likelihood of each of those things occurring and assessed the consequences of their happening. Likelihood combined with consequences equals risk.

"Events that represent a great-enough risk are investigated further, and a separate analysis is done for each one," says Paul Dixon, deputy postclosure science integration manager. "We develop models of the individual processes that allow us to estimate the dose associated with each event. Then for TSPA, you evaluate all of these ‘process models' together and come up with a prediction of the total dose to a person living in the region at any time in the future."

In the baseline scenario, very little happens inside the repository over the million-year regulatory period. There are no disruptive events such as earthquakes or volcanic eruptions. The engineered barriers remain intact, water reaches only a few waste packages, few waste packages ever corrode, and the waste stays within the repository.

In TSPA simulations, that scenario almost never plays out. That's because as time goes by, disruptive events, even improbable ones, become increasingly likely to occur. Earthquakes could knock the waste packages off their stands, rocks could fall from the ceiling and crack the drip shield, tunnels could collapse, or, in a very unlikely event, a volcano could rip through the repository.

Disruptive events, along with undetected faulty welds or material defects, are the repository's Achilles' heel. They could crack the waste packages, or at a minimum, allow water to contact the waste packages and begin a millennia-long corrosion process.

In the TSPA, these low-probability events eventually breach the waste packages, and water dissolves the waste material from the damaged waste packages. Once they are in solution, radionuclides can start to migrate through the 800–1,000-foot-thick layers of porous volcanic rock.

The rock's pores are only partially filled with water (it is "unsaturated"), but under the pull of gravity, the contaminated water percolates downward, and the radionuclides perform a random dance in which they bind to then break free of the rock surface. There are several such dances—sorption is one, mineralization is another—and which one occurs depends on the composition and chemical structure of the radionuclides and the rock surface, the pH of the water, and other parameters.

After several hundreds to many thousands of years, the particles reach the water table, where pressure differences cause the water to flow through "saturated" rock. The radionuclides again bind and breakdance their way through the rock for about 11 miles, at which point they might be pumped to the surface. If not brought up, the radioactive material would remain trapped below in the nearby desert, which is a closed water basin.